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Exhaust Emissions from High-Mileage Catalyst-Equipped Passenger Cars

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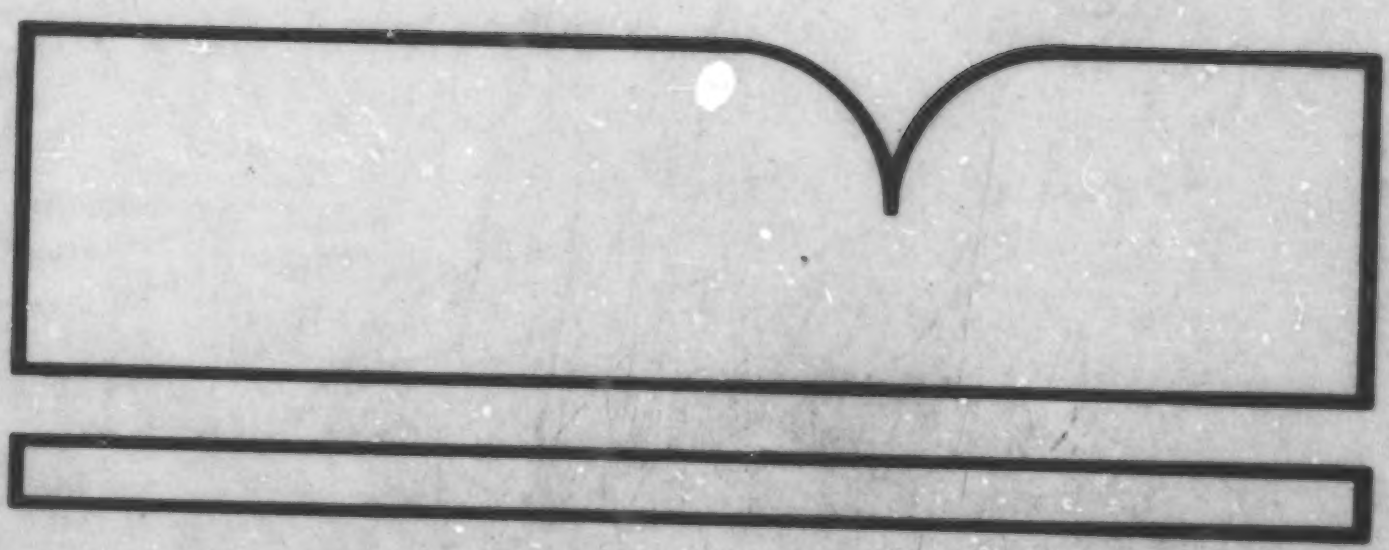

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Exhaust Emissions from High-Mileage, Catalyst-Equipped Passenger Cars

by

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July 1981

Test and Evaluation Branch
Emission Control Technology Division
Motor Vehicle Emission Laboratory
U.S. Environmental Protection Agency

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16. ABSTRACT

This report consolidates results from a number of emission testing programs on in-use passenger cars. Vehicles from the 1975 through 1981 model years were involved. The purpose of this effort was to examine the effect of "high mileage" on levels of exhaust emissions. The emission levels from the vehicles involved were examined from four basic views: 1) "As received" results of the top 15% (by odometer) versus similar results from the bottom 15% and 85%; 2) "as received" results of vehicles with over 50,000 miles versus those with under 50,000; 3) the effects of restorative maintenance on high mileage vehicles; and 4) the effects of catalyst replacement on high mileage vehicles.

The results show that the high mileage vehicles exhibit higher average HC and CO emissions than the lower mileage vehicles. The higher emission levels appear to be due to an increased rate of maladjustments, disablements and defective parts. It was also found that on the average, catalytic converters remain active beyond a vehicle's statutory "useful life" of 50,000 miles and that restorative maintenance is an effective method to reduce average emission levels. Even further reductions were possible, especially in HC, through replacement of the catalytic unit.

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Abstract

This report consolidates results from a number of emission testing programs on in-use passenger cars. Vehicles from the 1975 through 1981 model years were involved. The purpose of this effort was to examine the effect of "high mileage" on levels of exhaust emissions. The emission levels from the vehicles involved were examined from four basic views: 1) "As received" results of the top 15% (by odometer) versus similar results from the bottom 15% and 85%; 2) "as received" results of vehicles with over 50,000 miles versus those with under 50,000; 3) the effects of restorative maintenance on high mileage vehicles; and 4) the effects of catalyst replacement on high mileage vehicles.

The results show that the high mileage vehicles exhibit higher average HC and CO emissions than the lower mileage vehicles. The higher emission levels appear to be due to an increased rate of maladjustments, disablements and defective parts. It was also found that on the average, catalytic converters remain active beyond a vehicle's statutory "useful life" of 50,000 miles and that restorative maintenance is an effective method to reduce average emission levels. Even further reductions were possible, especially in HC, through replacement of the catalytic unit.

Background

Federal Regulations which pertain to light duty vehicle (passenger car) emissions define "the useful life" of a vehicle as 5 years or 50,000 miles, whichever occurs first. EPA surveillance studies of passenger cars have demonstrated that even low-mileage, relatively new vehicles can exhibit poor average emission performance when compared to applicable standards (Reference 1). When this finding is combined with the fact that many catalyst equipped vehicles have now exceeded the 50,000 miles of their "useful life", it is clear that an assessment of these vehicles must be made to evaluate their impact on air quality. This report collects and presents the data from a number of programs in which high mileage vehicles were tested.

Program Design

The data from a number of programs were consolidated and categorized into four groups. Table 1 is a listing of the programs from which these data were gathered. Two of these data groups represent "as-received" results only. These two groups use the same data base, but are subjected to different analyses. The remaining two groups show both as-received results and the effect of maintenance actions on the emission levels of high mileage vehicles.

Table 1

Program Title	Sites
FY 75 Emission Factors	Chicago, St. Louis, Houston, Denver, Los Angeles, Washington, D.C., Phoenix
FY77 Emission Factors	Chicago, St. Louis, Houston, Denver, Washington, D.C., Phoenix
FY79 Emission Factors	St. Louis, Houston, Denver, Washington, D.C., Phoenix, Los Angeles
FY80 Emission Factors	San Antonio, Denver, Los Angeles
Restorative Maintenance Testing of High Mileage Vehicles at High Altitude	Denver
Restorative Maintenance and Catalyst Replacement on High Mileage Passenger Cars	St. Louis
California Air Resources Board High Mileage Catalyst Vehicle Surveillance Test Program	Los Angeles
A Study of Exhaust Emissions from 1975-1979 Model Year Passenger Cars in Los Angeles	Los Angeles

Data from the FY75, FY77, FY79, and FY80 Emission Factor programs were utilized for the two "as received" analyses. The first was in a format of comparing the emissions from the top 15% (by odometer reading) of the vehicles against the remaining 85%. Results from the bottom 15% were also addressed in some cases. The 15% figure was chosen arbitrarily to secure a reasonable sample size while still allowing a wide difference in average odometer readings. The second method was to divide the vehicles into two categories by a mileage cutpoint: odometer reading over 50,000 miles versus odometer readings under 50,000 miles. Because of the different standards these vehicles were designed to meet, the data is displayed as an average of the "percent of standards". This allows the data to be grouped together for direct comparison. This method is utilized in Figures 2, 3, 4, 6, 7 and 8. Shown in Table 2 is a listing of the Federal Standards which apply to these vehicles.

Table 2 - Exhaust Emission Standards for Passenger Cars (grams/mile)

	------Federal-------			-----California------		
Model Year	HC	CO	NOx	HC	CO	NOx
1975	1.5	15	3.1	0.9	9.0	2.0
1976	1.5	15	3.1	0.9	9.0	2.0
1977	1.5	15	2.0	0.41	9.0	1.5
1978	1.5	15	2.0	0.41	9.0	1.5
1979	1.5	15	2.0	0.41	9.0	1.5
1980	0.41	7.0	2.0	0.41(c)	9.0	1.0(d)
1981	0.41	3.4(a)	1.0(b)	A 0.41(c)	3.4	1.0(d)
				B 0.41(c)	7.0	0.7

(a) Waiver up to 7.0 gm/mi possible.

(b) Waiver up to 1.5 gm/mi possible for diesel or innovative technology.

(c) .39 gm/mi standard for hydrocarbons other than methane if methane is actually measured.

(d) 1.5 gm/mi allowed with 100,000 mile durability.

Note: For the 1981 model year, manufacturers may choose options A or B separately for their gasoline and diesel product lines in California. The option chosen in 1981 must be retained for the 1982 model year.

The third group of data dealt with the effects of maintenance on emission levels. This phase of the high-mileage testing incorporated the same basic philosophy as earlier Restorative Maintenance (RM) Programs, i.e., testing in as-received condition followed by successive stages of maintenance and retesting until the vehicle either meets its applicable standards or receives a major tune-up with replacement of any defective emission-related components (except the catalyst).

The fourth and final data group examined was restorative maintenance with catalyst replacement. The catalyst replacement was performed after the final test in the standard RM procedure. This allowed a direct comparison of catalyst efficiency.

Discussion of Results

The first group of data utilizes the results from the FY75, FY77, and FY79 Emission Factors programs. The vehicles were sorted by model year, and each model year was divided into three categories on the basis of odometer reading. The first category consisted of the top 15% (by odometer) of the vehicles and the second and third consisted of the bottom 15% and 85%. Although this method results in decreasing differences as the model years progress, there is still a substantial spread in the average odometer reading. Figure 1 displays this trend along with the number of vehicles tested in each category. Overall, the average odometer was 42,400 for the top 15%, 17,700 for the bottom 85% and 7200 for the bottom 15%. Because of many very small differences between the bottom 15% and the bottom 85%, the results from bottom 15% are not displayed graphically, but are discussed in the narrative.

Figures 2, 3, and 4 display the average HC, CO, and NOx emission levels for the top 15% and bottom 85% by model year. As shown in Figure 2, every model year, with the exception of 1980, displayed higher average HC levels on the high mileage vehicles than on the vehicles with lower mileage. One explanation for the unexpected results in the 1980 model year is that the average odometer for the bottom 85% was only 4100 miles. Thus, some "green engine effect" may still be evident. The small sample sizes may also have an effect. On an overall basis, the average HC of the high mileage group was 160% of standard, the 85% group averaged 120% of the standard and the bottom 15% averaged 96% of the standard. Figure 3 displays average CO. In each model year, the CO level was higher for the higher mileage vehicles. Overall, the average CO was 220% of standard for the high mileage vehicles, 160% of standard for the 85% group and 140% of the standard for the bottom 15%. Figure 4 shows no clear trend for the average NOx emissions. On an overall basis, there does not appear to be a significant difference in average NOx between the high and low mileage vehicles. A reason for this is that EGR problems which may cause higher NOx values are offset by problems which result in richer mixtures and, thus, supress formation of NOx.

This method of grouping was also applied to a sample that contained only three-way catalyst vehicles. This sample consisted of 428 late model vehicles in which there was little difference in the average odometer of the bottom 15% and the bottom 85%. For this reason, only the top 15% and the bottom 85% were compared. Listed in Table 3 are the "percent of standards" results for these vehicles. The clear trend toward higher emissions with higher mileage does not appear as evident here as it was with the earlier systems.

Table 3
Vehicles Equipped with 3-Way Catalysts

Model Year	Group	N	Average Odometer	--Percent of Standard-- HC	CO	NOx
1978	Top 15%	7	35384	98	77	89
	Bottom 85%	35	17158	166	80	69
1979	Top 15%	26	20419	165	74	89
	Bottom 85%	143	8181	134	90	73
1980	Top 15%	12	22006	187	168	66
	Bottom 85%	65	8899	117	116	74
1981	Top 15%	23	10702	100	213	64
	Bottom 85%	117	4486	110	217	55
Overall	Top 15%	68	18953	140	138	76
	Bottom 85%	360	7983	126	135	67

As shown, there are many inconsistences present in the model year breakdown. On an overall basis, average emissions were slightly higher in the top 15%.

The second group of results used the same data base as the first group. However, instead of breaking down each model year into a percentile grouping, a division point of 50,000 miles was used. This reduced the number of model years because of the lack of any 1979 or newer vehicles with over 50,000 miles in the data base. Figure 5 provides information on the average odometer and the number of vehicles in each category. The overall average odometer reading for the high mileage group was 62,200 miles while the average for the lower mileage vehicles was 23,200. In each model year, average HC from the high mileage group exceeded that of the low mileage vehicles (Figure 6). The overall average HC for the high mileage vehicles was twice their standards. The average HC for the lower mileage vehicles was 30% over their standards. Figure 7 displays the average CO results of these vehicles. The 1978 model year group showed the only unexpected results with slightly lower CO levels for the high mileage group which contained only 9 cars. Overall, the high mileage vehicles displayed an average CO level that was 250% of standard while the low mileage vehicles displayed 180% of standard. As in the 15-85-15 data group, NOx did not display a clear trend. In fact, it was an identical 92% of standard for the overall average on both the high and low mileage groups (Figure 8). Although it appears the overall average should be different, the sample sizes of the groups with largest apparent differences were relatively small.

The third group of data consisted of 133 high-mileage vehicles (average odometer: 66,500) that underwent RM testing in St. Louis, Denver and Los Angeles (Reference 2, 3, 4, 5). The majority of the vehicles were 1975 and 1976 models although a few 1977 models were included. The collective results from these programs are shown in Figure 9. As in other RM programs on vehicles with lower mileage, substantial improvements in

emission levels were displayed after maintenance. However, only average NOx was reduced below its standard. When compared to lower mileage vehicles tested in other RM programs, the percentage reductions in the emission levels appear similar although the final levels achieved were not as low. These results are further confirmed by an earlier Restorative Maintenance retesting program in the Detroit area (Reference 6) in which thirteen 1975 model year vehicles received three RM testing sequences over a two year period. The time interval for the second and third tests were approximately twelve months and eighteen months after the first test. The average odometer for each test point was 9,900 (first test), 27,000 (second test), and 36,000 (third test). The results from this program show deterioration in the average emission levels of the retested vehicles in both their "as-received" and "tuned-up" condition. Restorative Maintenance reduced the levels in the second and third tests to close to the lowest levels of the first test point. However, as the mileage increased on these vehicles, the average HC and CO emission levels of the "tuned-up" vehicles never quite achieved the levels of the preceding tests. Between the first and last test (approximately 26,000 miles) the average "tuned-up" HC and CO increased 29% and 53% respectively.

No significant findings were obtained upon sorting the 133 car group by manufacturer. The highest "as-received" HC was achieved by the Ford as 227% of the standard. The highest CO was 311% of standards achieved by GM vehicles. The highest NOx was 199% of standard achieved by the Chrysler vehicle average. Chrysler achieved the lowest as-received HC and CO values (137% and 188%, respectively). As a group, imported vehicles displayed the lowest as-received NOx value (101% of standard). After undergoing maintenance, vehicles from all manufacturers displayed decreases in each of the regulated pollutants. However, on the average, none of the manufacturer groups passed their-standards for all three.

The fourth and final group of data consisted of twenty-one 1975 and 1976 model year vehicles (average odometer: 87,000 miles) that underwent restorative maintenance procedures in St. Louis and Denver (Reference 7, and 8). After the final test in the standard RM procedure, the catalyst was replaced with a new unit and the vehicle was retested.

Figure 10 displays the emission reductions which occurred during the different phases of this testing. As expected, a drop in the emission levels occurred after the major tune-up and component replacement were performed, although only NOx was reduced to below its standard. After replacing the catalyst, HC dropped 43% and CO dropped 14%. This brought average HC below its standard while CO was still above. The new catalyst obviously had an impact on reducing the emission levels of these vehicles. However, the replacement catalysts were new and had not been conditioned in any way. The efficiency of these fresh units would likely decrease slightly and level off after some mileage accumulation.

An additional area of evaluation involved eight vehicles tested in St. Louis that had an average odometer of 104,000 miles. This step consisted of replacing the old catalyst with a plain section of pipe (with restrictions to duplicate the back pressure). The test performed after these actions showed evidence of the old catalyst's activity because of

the emission increases witnessed Average HC was up 87%, average CO was up 66%, and average NOx remained virtually unchanged. This indicates that the converters displayed catalytic activity well beyond their "useful life". When the new catalysts were installed on these eight vehicles, average HC and CO emission levels fell below the best levels achieved with the old catalysts. This implies that although the old units were still active, they were not as efficient as the new units.

Cause Analysis

The data presented has established a definite correlation between higher mileage and increased emissions. Two possible reasons behind the increases are a higher rate of defective parts and/or an increase in the number of maladjustments and disablements. Upon examination of the data from the underhood inspection forms, it was determined that both of these factors were predominant. On the 15-85 vehicle group, it was revealed that 92% of the high mileage vehicles were maladjusted and/or disabled compared to 80% of the lower mileage vehicles. The rate of defective parts was 25% for the high mileage vehicles versus 10% for the low mileage vehicles. The higher rate of defective parts is probably due to greater deterioration caused by the increased usage factors. Shown in Table 3 are the pass-fail rates of the individual control systems. In each case, the high mileage group displayed higher failure rates than the lower mileage vehicles. This data suggests that as mileage increases, so does the rate of maladjustments, disablements, and defective parts. The ability to reduce the emission levels of these vehicles through restorative maintenance was clearly shown in the RM programs mentioned earlier.

Table 3
System Inspection Failure Rates*

System	Bottom 85%	Top 15%
Induction	17	30
Fuel	75	88
Choke	42	55
Ignition	33	48
Air Pump	3	22
EGR	8	19
PCV	11	18
Evap.	4	11
Exhaust	0	2

*Note: A maladjustment/disablement and/or a defective part are the criteria for failing a system. Numbers are expressed as a percentage of system failures on vehicles equipped with the subject system.

Conclusions

The results of the above analysis show that the higher mileage vehicles had significantly higher average HC and CO emissions "as-received" than similar vehicles with lower mileage. NOx emission levels were approximately the same. The higher emission levels on the high mileage

vehicles appear to be due to a higher rate of maladjustment/disablement actions and defective parts.

Restorative maintenance was effective in reducing the average emission levels on the high mileage vehicles. However, only average NOx was reduced to below its standard. Catalyst replacement was effective in further reducing emission levels after standard RM procedures. Even though the new catalysts displayed an improvement over the old catalysts, the original units were still reasonably effective beyond their defined "useful life". Overall, the results of these programs display the durability of emission control systems and the ability of high mileage vehicles to respond favorably to proper maintenance.

References

1. An Evaluation of Restorative Maintenance on Exhaust Emissions from In-Use Automobiles, J.T. White, SAE Paper 780082, March, 1978.

2. Evaluation of Restorative Maintenance and Catalyst Replacement on Exhaust Emissions from Eight Very High Mileage Passenger Cars in St. Louis, G.T. Jones, Report #79-10, June, 1979.

3. A Study of Exhaust Emissions from 1975-1979 Model Year Passenger Cars in Los Angeles, Lawrence Moore and Donald C. Unger, Jr., EPA-460/3-79-004, July, 1979.

4. Restorative Maintenance Testing of High Mileage Vehicles at High Altitude, Automotive Testing Laboratories, Inc., Work Effort No. 3, Contract No. 68-03-2612, August, 1978.

5. Final Report of the High Mileage Catalyst Vehicle Surveillance Test Program, California Air Resources Board, MS-80-002, December, 1979.

6. Evaluation of Restorative Maintenance Retesting of Passenger Cars in Detroit, G.T. Jones, Report #79-5, January, 1979.

7. Op. Cit. #4

8. Op. Cit. #2

Figure 1: Average Odometer (85% vs. 15%)

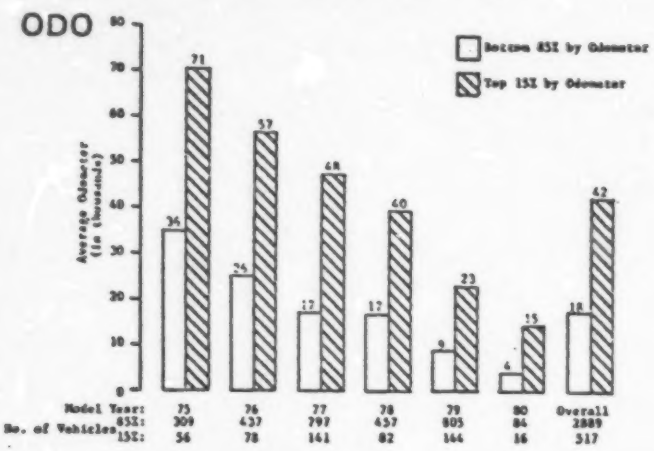

ODO
Bottom 85% by Odometer
Top 15% by Odometer
Average Odometer (In Thousands)
Model Year: 75 76 77 78 79 80 Overall
No. of Vehicles 85%: 309 437 797 457 805 84 2889
No. of Vehicles 15%: 56 78 141 82 144 16 517

Figure 2: As-Received FTP HC (85% vs. 15%)

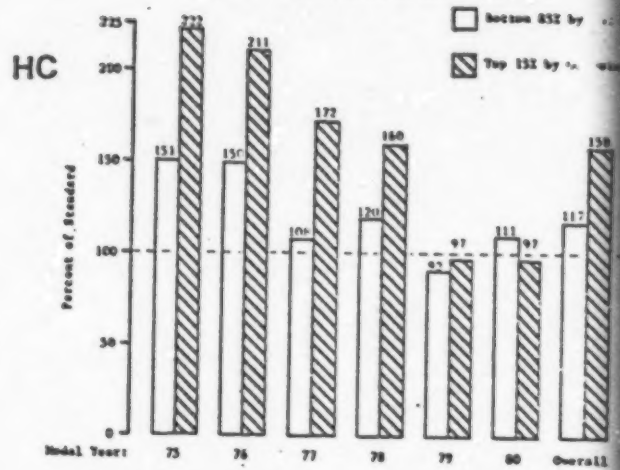


Figure 3: As-Received FTP CO (85% vs. 15%)

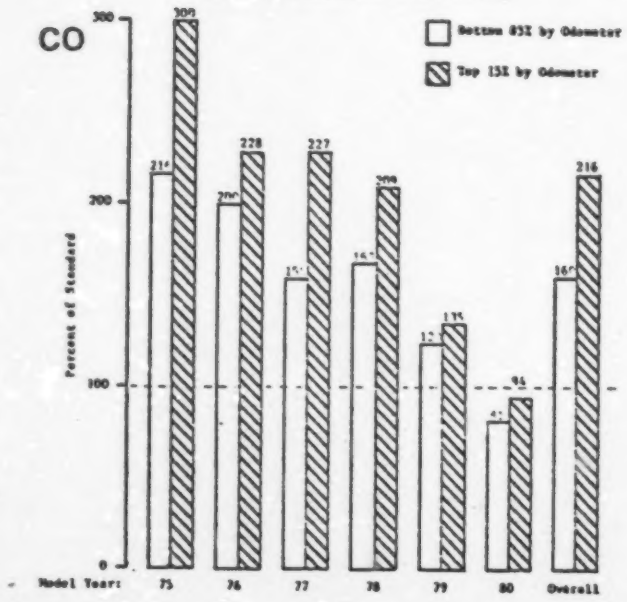
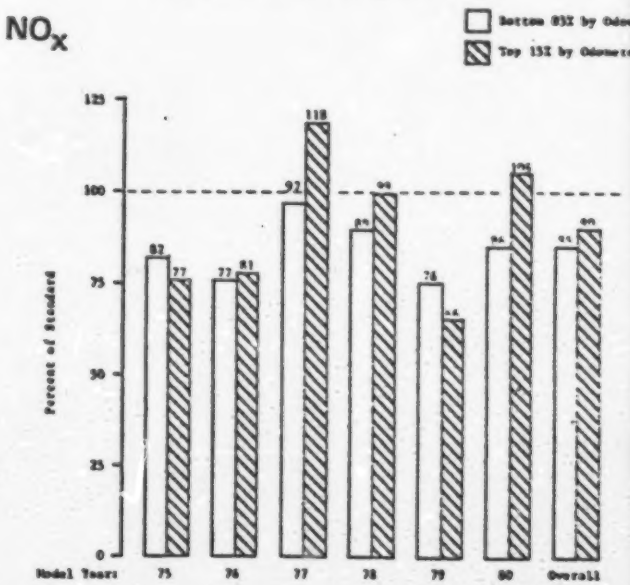
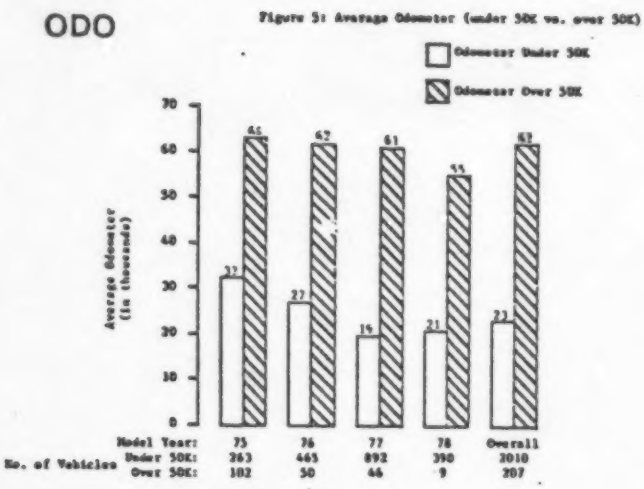


Figure 4: As-Received FTP NO_x (85% vs. 15%)



ODO

Figure 5: Average Odometer (under 50K vs. over 50K)



HC

Figure 6: As-Received FTP HC (under 50K vs. over 50K)

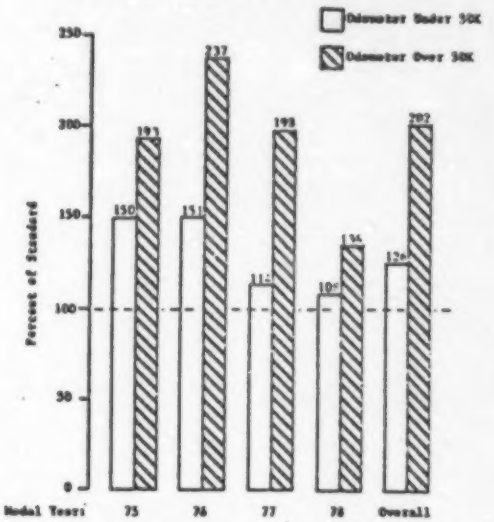
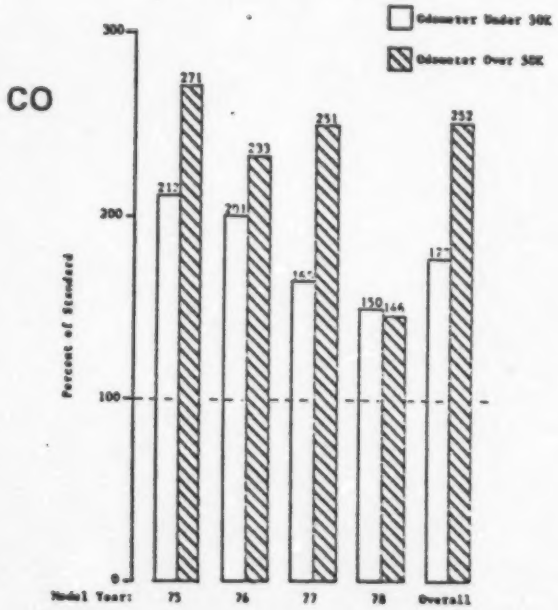


Figure 7: AS-Received FTP CO (under 50K vs. over 50K)



NO_x

Figure 8: As-Received FTP NO_x (under 50K vs. over 50K)

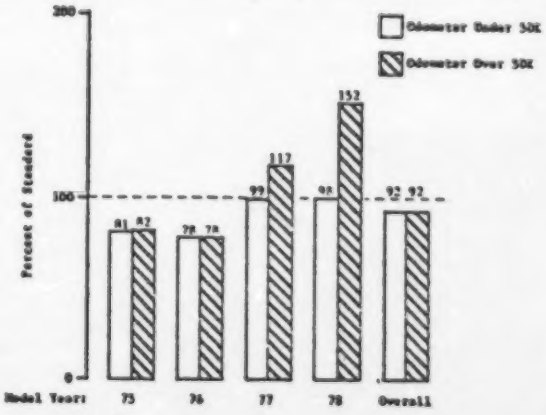


Figure 9: Restorative Maintenance on 133
1975, 1976 and 1977 High Mileage Vehicles
Average Odometer: 66,500

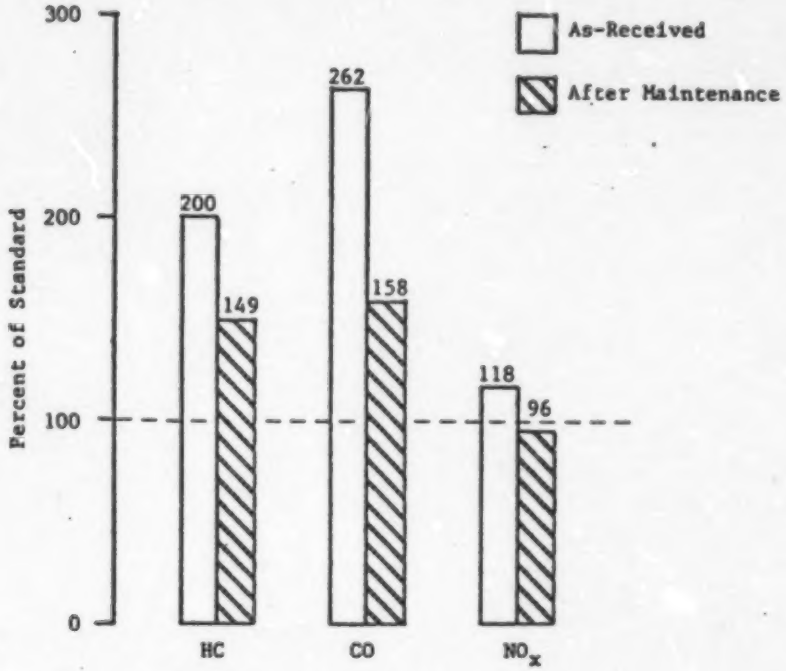


Figure 10: Restorative Maintenance and Catalyst
Replacement on 21 1975 and 1976 High MileageVehicles
Average Odometer: 87,000